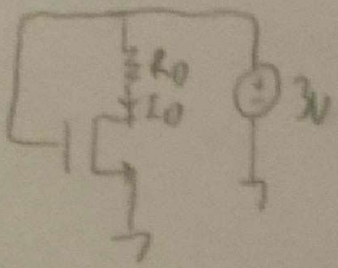
ECE 100 Final Exam Solutions

a)



$V_G = 3V$

$V_S = 0V$

$V_{DS} = V_{GS} - V_T$ (Edge of saturation) (1)

$= 3 - 0.5 = 2.5V$

$I_D = K(V_{GS} - V_{TH})^2$ (1)

$= 0.3 \cdot 10^{-3} (2.5)^2$

$= 1.875mA$

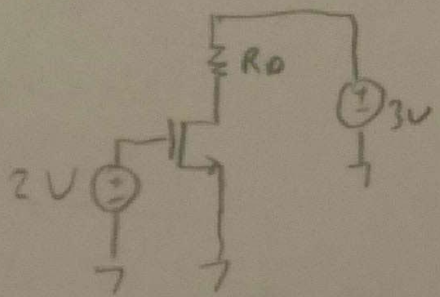
$V_D = V_{GS} - V_{TH} = 3V - I_D R_D$ (1)

$2.5 = 3V - I_D R_D$

$0.5 = I_D R_D$

$\frac{0.5}{1.875 \cdot 10^{-3}} = R_D \Rightarrow$ $\boxed{R_D = 266.67\Omega}$ (2)

b)



$V_G = 2V$

$V_S = 0V$

$V_D = V_{GS} - V_T$ (Edge of Saturation) (1)

$= 2 - 0.5 = 1.5V$

$I_D = k(V_{GS} - V_{TH})^2$ (1)

$= 0.3 \cdot 10^{-3} (1.5)^2$

$= 6.75 \cdot 10^{-4} A$

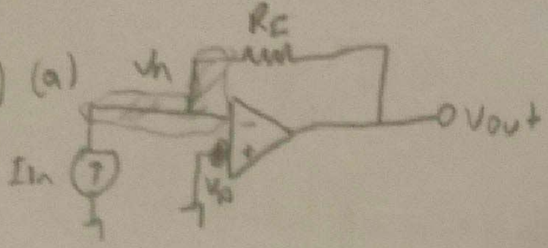
$V_D = V_{GS} - V_{TH} = 3 - I_D R_D$ (1)

$1.5 = 3 - I_D R_D$

$1.5 = I_D R_D$

$\boxed{2222.22\Omega = R_D}$ (2)

2) (a)



Node eqn at V_n

$$-I_{in} + \frac{V_n - V_{out}}{R_F} = 0$$

$V_p = 0$

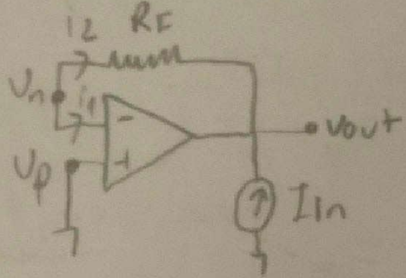
$V_n = V_p = 0$

$$-I_{in} - \frac{V_{out}}{R_F} = 0$$

$$\boxed{V_{out} = -I_{in} R_F}$$

(2)

(b)



$V_p = 0$

$V_n = V_p = 0$

Node eq. at V_n

$i_1 + i_2 = 0$

$i_1 = 0$ due to ideal opamp

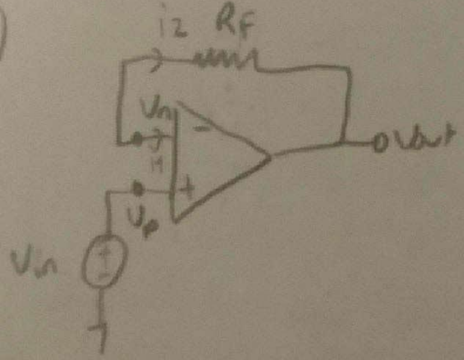
$$i_2 = 0 \Rightarrow \frac{V_n - V_{out}}{R_F} = 0$$

$V_n = V_{out}$

$$\boxed{0 = V_{out}}$$

(2)

(c)



$V_p = V_n$

$V_p = V_{in} = V_n$

Node eq. at V_n

$i_1 + i_2 = 0$

$i_1 = 0$ due to ideal opamp

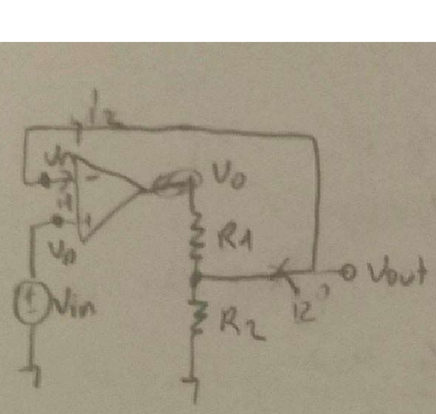
$$i_2 = 0 \Rightarrow \frac{V_n - V_{out}}{R_F} = 0$$

$V_n = V_{out}$

$$\boxed{V_{in} = V_{out}}$$

(2)

d)

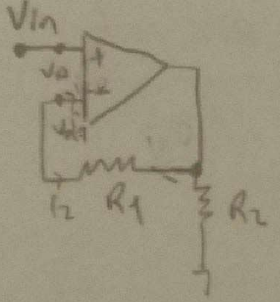


$V_p = V_{in}$

$V_n = V_p = V_{in}$

$\boxed{V_n = V_{out} = V_{in}}$ (2)

e)



$V_p = V_n = V_{in}$

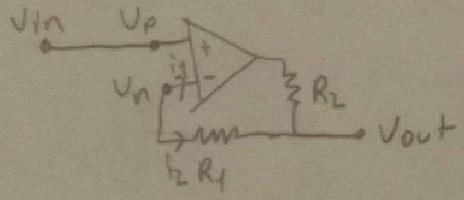
$I_1 + I_2 = 0$ (Node eqn at V_n)

$I_1 = 0$ due to ideal op-amp

$I_2 = 0 = \frac{V_n - V_{out}}{R_1}$

$\boxed{V_n = V_{out} = V_{in}}$ (2)

f)



$V_p = V_{in}$

$V_n = V_p = V_{in}$

Node eqn at V_n

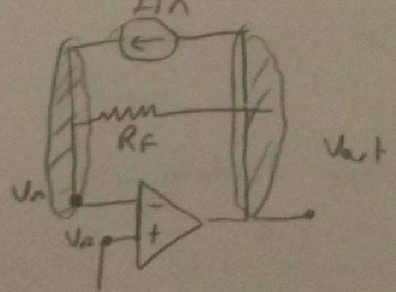
$I_1 + I_2 = 0$

$I_1 = 0$ due to ideal opamp

$I_2 = 0 = \frac{V_n - V_{out}}{R_1} \Rightarrow \boxed{V_n = V_{out} = V_{in}}$

(2)

g)



$V_p = 0$

$V_p = V_n = 0$

Node eqn at V_n:

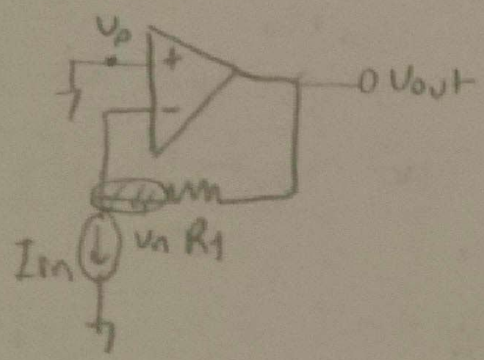
$-I_{in} + \frac{V_n - V_{out}}{R_F} = 0$

$V_n - V_{out} = I_{in} R_F$

0

$\boxed{V_{out} = -I_{in} R_F}$ (2)

h)



$V_p = 0$

$V_n = V_p = 0$

Node eqn at V_n:

$$\frac{V_n - V_{out}}{R_1} + I_n = 0$$

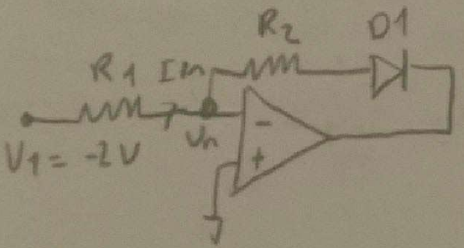
0

$$\boxed{I_n \cdot R_1 = V_{out}}$$

(2)

3)

a)



$V_n = V_p = 0$

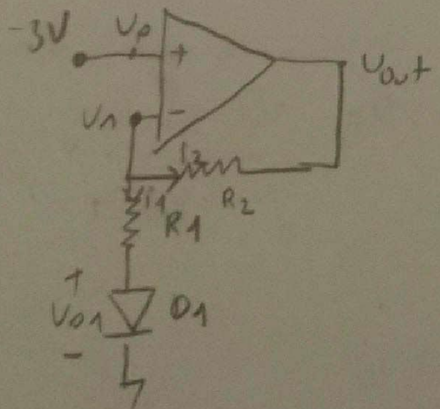
$$I_n = \frac{-2 - V_n}{R_1} = \frac{-2}{R_1}$$

For D1 to be ON $I_n > 0$ however

$I_n = \frac{-2}{R_1}$ Therefore it is OFF

(4)

b)



$V_p = -3V$

$V_p = V_n = -3V$

Assume off for diode

Node eq at V_n:

$i_1 + i_2 = 0$

$i_1 = 0$ because diode is off

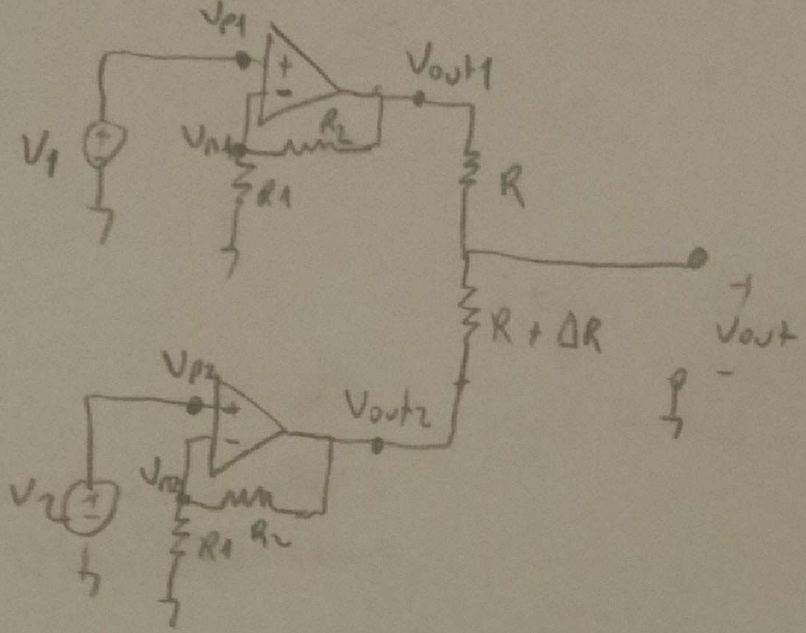
$i_2 = 0 \Rightarrow \frac{V_n - V_{out}}{R_2} = 0 \quad V_n = V_{out} = -3V$

$V_{D1} = V_n - i_1 R_1 = -3 - 0 = -3V < 0$

Diode is OFF

(4)

4)



$V_1 = V_2$

$V_{p1} = V_1 \qquad V_{p1} = V_{n1} = V_1$

Node eqn at V_{n1}

$$\frac{V_{n1} - V_{out1}}{R_2} + \frac{V_{n1}}{R_1} = 0$$

$$\frac{V_{out1}}{R_2} = V_1 \left(\frac{R_1 + R_2}{R_1 R_2} \right)$$

$$V_{out1} = V_1 \left(\frac{R_1 + R_2}{R_1} \right) \quad (2)$$

Similarly $V_{out2} = V_2 \left(\frac{R_1 + R_2}{R_1} \right)$

Node eqn at V_{out}

$$\frac{V_{out} - V_{out1}}{R} + \frac{V_{out} - V_{out2}}{R + \Delta R} = 0$$

$$V_{out}(R + \Delta R) - V_{out1}(R + \Delta R) + V_{out} R - V_{out2} R = 0$$

$$V_{out}(2R + \Delta R) = V_{out1}(R + \Delta R) + V_{out2} R$$

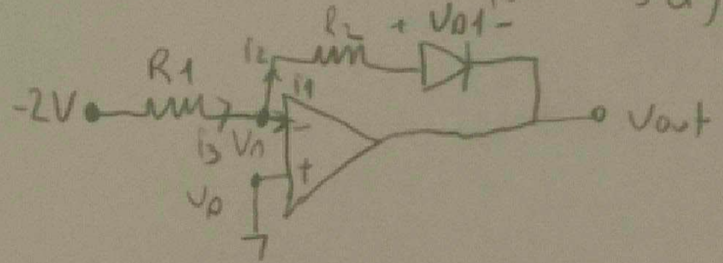
$$V_{out}(2R + \Delta R) = V_1 \left(\frac{R_1 + R_2}{R_1} \right)(R + \Delta R) + V_2 \left(\frac{R_1 + R_2}{R_1} \right) R$$

$$V_{out} = \frac{\left(\frac{R_1 + R_2}{R_1} \right) \left[V_1 (R + \Delta R) + V_2 R \right]}{2R + \Delta R}$$

For an explied pattent $V_1 = V_2$ (2)

$V_{out} = \left(\frac{R_1 + R_2}{R_1}\right) V_1$ // (2)

Extra clarification for 3a)



$V_p = 0$

If the diode is OFF, eventually $V_n \neq 0$

If $V_n = 0$ then there would be some I_3 which needs to flow somewhere. Since the Diode is OFF, I_2 must be zero.

$I_3 = I_1 + I_2$ $\quad I_1 = 0$ because ideal op-amp

$I_2 = 0$ because diode is OFF

$I_3 = 0$

For $I_3 = 0$ $\quad V_n = -2V \Rightarrow$ If $V_n = -2V$

$V_{out} = A(V_p - V_n) = \lim_{A \to \infty} A(0 - (-2)) = \infty$

The diode will have a voltage $\Rightarrow V_{01} = -2 - \infty = -\infty < 0$

So the diode is OFF

∴ Kirchhoff rests peacefully in his heaven!